

## CLAIMS

1. A carbon fiber precursor fiber bundle, characterized by:  
having  $1 \text{ m}^{-1}$  or less of a degree of intermingle between a plurality of small tows based on the hook drop method;  
consisting of substantially straight fibers without imparted crimp, a tow of which straight fibers has a moisture content of less than 10% by mass when housed in a container; and  
having a widthwise dividing capability to maintain a form of a single aggregate of tows when housed in a container, taken out from the container and guided into a firing step, and to divide into a plurality of small tows in the firing step by the tension generated in the firing step;
2. The carbon fiber precursor fiber bundle according to claim 1, wherein the monofilament fineness is 0.7 dtex or more and 1.3 dtex or less, the number of monofilaments of the small tow is 50,000 or more and 150,000 or less, and the total number of monofilaments in the aggregate of tows is 100,000 or more and 600,000 or less.
3. The carbon fiber precursor fiber bundle according to claims 1 or 2, wherein the aggregate of tows is formed by intermingling monofilaments between a widthwise end of a small tow and a widthwise end of the adjacent small tow by air flow.
4. The carbon fiber precursor fiber bundle according to any one of claims 1 to 3, wherein the number of monofilaments undergoing adhesion between the monofilaments is 5 per 50,000 of monofilaments or less and the size of the crystal region in a direction perpendicular to the fiber axis is  $1.1 \times 10^{-8} \text{ m}$  or more.

5. The carbon fiber precursor fiber bundle according to any one of claims 1 to 4, wherein the strength of a monofilament is 5.0 cN/dtex or more, and the fineness unevenness (CV value) of the monofilament is 10% or less.

6. The carbon fiber precursor fiber bundle according to any one of claims 1 to 5, wherein the oiling agent adhesion unevenness (CV value) along the lengthwise direction is 10% or less.

7. A production method of a carbon fiber precursor fiber bundle, characterized by comprising:

a coagulation step of forming swollen yarn by extruding an organic solvent solution of an acrylonitrile-based polymer into an aqueous solution of dimethylacetamide from a spinning nozzle having a nozzle hole diameter of 45  $\mu\text{m}$  or more and 75  $\mu\text{m}$  or less and the number of holes of 50,000 or more at a coagulated yarn take-up speed/extrusion linear speed ratio of 0.8 or less;

a wet heat drawing step of wet heat drawing the swollen yarn;

an oiling agent imparting step of imparting a first oiling agent to the wet heat drawn yarn by guiding the heat wet drawn yarn into a first oil bath, and subsequently imparting a second oiling agent in a second oil bath after once squeezing the yarn by use of two or more guides;

a small tow production step of obtaining a small tow by drying, densifying and secondarily drawing the yarn imparted with the first and second oiling agents so as to have a total drawing magnification of 5 or more and 10 or less; and

an aggregate-of-tows production step of obtaining an aggregate of tows by feeding a plurality of the small tows so as to be in parallel and adjacent to each other into an intermingling device that comprises a yarn channel having a flat rectangular section and a plurality of air jet holes which are disposed with a predetermined interval along the long side direction of the flat rectangle and which

open into the yarn channel, and by jetting out air from the air jet holes to intermingle the adjacent small tows with each other.

8. The production method of a carbon fiber precursor fiber bundle according to claim 7, further comprising an aggregate-of-tows housing step of housing the aggregate of tows in a container after the aggregate-of-tows production step and a water imparting step of imparting water to the small tows before the aggregate-of-tows production step, wherein

the water content of the aggregate of tows in the aggregate-of-tows housing step is set at less than 10% by mass.

9. The production method of a carbon fiber precursor fiber bundle according to claims 7 or 8, further comprising, before the aggregate-of-tows production step, an intra-small-tow intermingling step of intermingling monofilaments within the small tow with each other by passing the small tow through an intermingling device, other than the intermingling device used in the aggregate-of-tows production step, that comprises a yarn channel having a circular section and an air jet hole which opens into this yarn channel, and by jetting out air from this air jet hole.

10. The production method of a carbon fiber precursor fiber bundle according to claims 7 or 8, further comprising, before the aggregate-of-tows production step, an intra-small-tow intermingling step of intermingling the monofilaments within the small tow with each other by passing the small tow through an intermingling device, other than the intermingling device used in the aggregate-of-tows production step, that comprises a yarn channel having a flat rectangular section and a plurality of air jet holes which are disposed with a predetermined interval along the long side direction of this flat rectangle and which open into this yarn channel, and by jetting out air from these air jet holes.

11. The production method of a carbon fiber precursor fiber bundle according to claims 7 or 8, wherein monofilaments within the small tow are intermingled with each other in the aggregate-of-tows production step.

12. The production method of a carbon fiber precursor fiber bundle according to claim 11, wherein the intermingling device, used in the aggregate-of-tows production step, further comprises a groove which extends along the lengthwise direction of the yarn channel and which opens into the yarn channel at a position where the small tows are adjacent to each other.

13. The production method of a carbon fiber precursor fiber bundle according to claims 9 or 10, wherein:

the intermingling device, used in the aggregate-of-tows production step, further comprises a groove which extends along the lengthwise direction of the yarn channel and which opens into the yarn channel at a position where the small tows are adjacent to each other, and the air jet holes open only into the groove; and a plurality of the small tows are intermingled with each other, wherein the filaments within the small tows are intermingled with each other, by feeding to this intermingling device the plurality of the small tows having been subjected to the intra-small-tow intermingling step.

14. The production method of a carbon fiber precursor fiber bundle according to any one of claims 7 to 13, further comprising a step of housing in a container the aggregate of tows obtained in the aggregate-of-tows production step after the aggregate of tows has been fed to a gear roll.

15. The production method of a carbon fiber precursor fiber bundle according to any one of claims 7 to 13, further comprising a step of housing in a container the aggregate of tows obtained in the aggregate-of-tows production step after the aggregate of tows has been fed to a nip roll.

16. A production apparatus of a carbon fiber precursor fiber bundle, characterized by comprising an intermingling device that comprises a yarn channel having a flat rectangular section capable of passing a plurality of small tows which are adjacent to each other and that comprises a plurality of air jet holes which are disposed with a predetermined interval along the long side direction of the flat rectangle and which open into the yarn channel.

17. The production apparatus of a carbon fiber precursor fiber bundle according to claim 16, further comprising a groove which extends along the lengthwise direction of the yarn channel and which opens into the yarn channel at a position where the plurality of small tows are adjacent to each other.

18. A production apparatus of a carbon fiber precursor fiber bundle, characterized by comprising:

a first intermingling device that comprises a yarn channel having a circular section capable of passing a small tow and that comprises one or more air jet holes for jetting out air into the yarn channel; and

a second intermingling device that comprises a yarn channel having a flat rectangular section capable of passing a plurality of small tows which are adjacent to each other and that comprises a plurality of air jet holes which are disposed with a predetermined interval along the long side direction of this flat rectangle and which open into this yarn channel.

19. A production apparatus of a carbon fiber precursor fiber bundle, characterized by comprising:

a first intermingling device that comprises a yarn channel having a flat rectangular section capable of passing a small tow and that comprises one or more air jet holes for jetting out air into the yarn channel; and

a second intermingling device that comprises a yarn channel having a flat rectangular section capable of passing a plurality of small tows which are adjacent

to each other and that comprises a plurality of air jet holes which are disposed with a predetermined interval along the long side direction of this flat rectangle and which open into this yarn channel.

20. The production apparatus of a carbon fiber precursor fiber bundle according to claims 18 or 19, wherein the second intermingling device further comprises a groove which extends along the lengthwise direction of the yarn channel thereof and which opens into the yarn channel at a position where the plurality of small tows are adjacent to each other.

21. The production apparatus of a carbon fiber precursor fiber bundle according to claim 20, wherein the air jet holes of the second intermingling device open only into the groove.

22. The production apparatus of a carbon fiber precursor fiber bundle according to claim 16, wherein the ratio  $n \cdot D/L$  of the total fineness  $nD$  (dTex) of an aggregate of tows represented by the product between the total fineness  $D$  (dTex) of the small tow and the number  $n$  of the small tows to be aggregated to the long side dimension  $L$  (mm) of the flat rectangular section is 2,000 dTex/mm or more and 12,000 dTex/mm or less, and the diameter of each of the air jet holes is 0.3 mm or more and 1.2 mm or less.

23. The production apparatus of a carbon fiber precursor fiber bundle according to claim 16, wherein the air jet holes are disposed with an even pitch, and the pitch is 0.8 mm or more and 1.6 mm or less, and the length of the yarn channel is 10 mm or more and 40 mm or less.

24. The production apparatus of a carbon fiber precursor fiber bundle according to claims 17 or 20, wherein the groove has a sectional shape of a part of a circle, and the diameter of the circle is 2 mm or more and 10 mm or less, and the depth of the groove is 1.5 mm or more and 4 mm or less.

25. The production apparatus of a carbon fiber precursor fiber bundle according to claims 17 or 20, wherein the groove has a trapezoidal sectional shape, and the dimension of the long side of the trapezoidal groove section is 2 mm or more and 10 mm or less, and the dimension of the short side corresponding to the groove bottom is 1.5 mm or more and 6 mm or less.

26. A production method of a carbon fiber, characterized in that the carbon fiber precursor fiber bundle according to any one of claims 1 to 6 is fed to a flame retarding step, and is fired while being divided into small tows by the tension generated in the flame retarding step.

27. A production method of a carbon fiber, characterized in that the carbon fiber precursor fiber bundle according to any one of claims 1 to 6 is fed to a carbonization step after a flame retarding step, and is fired while being divided into small tows by the tension generated in the carbonization step.

28. A carbon fiber characterized in that the carbon fiber is produced by the method according to claim 27 and the strand strength thereof defined by JIS R7601-1986 is 4100 MPa or more.

29. A production method of a carbon fiber precursor fiber bundle, characterized by comprising a step of obtaining a single aggregate of tows by disposing a plurality of small tows of carbon fiber precursor fiber so as to be in parallel and adjacent to each other, and by intermingling the adjacent small tows with each other by air flow.

30. The production method of a carbon fiber precursor fiber bundle according to claim 29, wherein, in the step of obtaining an aggregate of tows, the intermingling is carried out by feeding a plurality of the small tows so as to be in parallel and adjacent to each other into an intermingling device that comprises a yarn channel having a flat rectangular section and a plurality of air jet holes which are disposed

with a predetermined interval along the long side direction of the flat rectangle and which open into the yarn channel, and by jetting out air from the air jet holes.